

U.S. Department of Transportation Federal Aviation Administration

Advisory Circular

Subject: Runway Length Date: Draft AC No: 150/5325-4C

Recommendations for Airport Design Initiated by: AAS-100 Change:

- 1. What is the purpose of this AC? This Advisory Circular (AC) provides guidelines for
- 2 airport designers and planners to determine recommended runway lengths for new runways or
- 3 extensions to existing runways.
- 4 2. Does this AC cancel any prior ACs?
- 5 This AC cancels AC 150/5325-4B, titled Runway Length Requirements for Airport Design,
- 6 dated 7/1/2005.
- 7 3. To whom does this AC apply?
- 8 We recommend the standards and guidelines contained in this AC for use in the design of civil
- 9 airports. Do not use the guidelines, airplane performance data curves and tables, and the
- 10 referenced airplane manufacturer manuals as a substitute for flight planning calculations as
- required by airplane operating rules. You must use this AC for all projects funded with federal
- grant monies through the Airport Improvement Program (AIP) and/or with revenue from the
- Passenger Facility Charges (PFC) Program. See Grant Assurance No. 34, Policies, Standards,
- and Specifications, and PFC Assurance No. 9, Standards and Specifications.
- 4. Are there any related documents?
- Related documents to this AC are indicated in <u>Appendix 2</u>.
- 5. What are the principal changes in this AC?
- We revised the AC to provide guidance to determine runway lengths for planning purposes. We
- 19 now recommend using manufacturers' airport planning manuals to determine basic
- recommended runway lengths for all large (over 12,500 lbs. maximum takeoff weight) airplanes
- 21 and jets.
- 22 Michael J. O'Donnell
- 23 Director of Airport Safety and Standards

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85	* Boeing and Embraer granted permission for use of their charts	

Introduction Chapter 1.

101. Background.

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88 The runway length necessary for any particular airplane operation will depend on many factors, including the airport elevation, temperature, wind velocity, airplane operating weight, takeoff 89 90 and landing flap settings, runway surface condition (dry or wet), runway elevation range, presence of obstructions in the vicinity of the airport, and, if any, locally imposed noise 91 abatement restrictions or other prohibitions. Local lawmakers can establish zoning ordinances to 92 prohibit the introduction of man-made obstructions and require the removal of trees that 93 94 penetrate existing or planned runway approach and departure surfaces within their jurisdictions. Effective zoning ordinances can help prevent the need to displace runway thresholds or reduce 95

takeoff runway lengths. The selection of the design airplane(s) is a planning decision that may be 96 97

based on anticipated demand, and is beyond the scope of this AC.

Definitions. 102.

- Crosswind Runway. An additional runway that compensates for primary runways that provide less wind coverage than desired.
- Design Airplane(s). The airplane (or family of airplanes) that results in the longest recommended runway length.
- Effective Runway Gradient. The runway elevation range divided by the runway 103 length. 104
- Family of airplanes. For the purposes of this AC, a group of airplanes having similar 105 d. performance characteristics with respect to takeoff or landing. 106
 - Large Airplane. An airplane of more than 12,500 pounds (5,670 kg) maximum certificated takeoff weight.
 - Maximum Certificated Takeoff Weight (MTOW). The maximum certificated weight for the airplane at takeoff, i.e., the airplane's weight at the start of the takeoff run.
 - Primary Runway. For the purposes of this AC, a runway constructed strictly to meet airport capacity needs. Such runways are generally aligned as closely as possible to the prevailing wind, usually parallel to one another.
 - Regular Use. Federally funded projects require that design airplanes be based on a h. minimum number of annual operations, except for touch and go operations, (landings and takeoffs are considered as separate operations) of an individual airplane or a family grouping of airplanes with similar runway length requirements. See FAA Order 5100.38, Airport Improvement Program Handbook, for guidance on requirements for the minimum number of operations.
- Runway Elevation Range. The difference between the highest and lowest elevations 120 i. of the runway centerline. 121

j. Small Airplane. An airplane of 12,500 pounds (5,670 kg) or less maximum certificated takeoff weight.

124 103. Procedure and Rationale for Determining Recommended Runway Lengths.

- Perform the following steps, then proceed to Chapter 2 or Chapter 3 as appropriate,
 - a. Step #1. Identify the design airplane(s) that will require the longest runway at maximum certificated takeoff weight (MTOW) and at maximum landing weight (MLW). For federally funded projects, see paragraph 102.h regarding the selection of the design airplane(s). For other projects, the airport owner must select the design airplane(s) based on many factors such as economics, environmental concerns, and community needs.
- Step #2. Determine the mean daily maximum temperature of the hottest month of the 131 year. This information can be obtained from the publication "Monthly Station Normals of 132 Temperature, Precipitation, and Heating and Cooling Degree-Days" (Climatography of the 133 United States No.81). This is the official source for the mean maximum temperature for the 134 hottest month. The latest data, averaged over a period of thirty years, may be obtained from 135 NOAA's National Climatic Data Center, Veach-Baley Federal Building, 151 Patton Ave., 136 Asheville, North Carolina 28801. Phone: (828) 271-4800; fax: (828) 271-4876; or website: 137 http://www.ncdc.noaa.gov/customer-support. 138
- c. Step #3. For small propeller-driven airplanes, see <u>Chapter 2</u>. For large airplanes and light jets, see <u>Chapter 3</u>.

104. Primary Runways.

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Most airports provide a single primary runway. In some cases, two or more primary runways are 142 needed to achieve airport operational objectives. Additional primary runways for an increase in 143 capacity are usually parallel to and equal in length to the existing primary runway, unless they 144 are intended for smaller, slower airplanes. Refer to AC 150/5060-5, Airport Capacity and Delay, 145 for additional discussion on runway usage for capacity gains. It is common to assign individual 146 primary runways to different airplane classes. Separating smaller, slower airplanes from larger, 147 faster airplanes will often increase the airport's efficiency. The design objective for a primary 148 runway is to provide a runway length that will not result in operational weight restrictions. For 149 federally funded projects, the criterion for regular use applies (see paragraph 102.h) Guidance 150 on additional primary runways is provided in Table 1-1. The table takes into account the 151 separation of airplanes into airplane families with similar performance to achieve greater airport 152 utilization. Follow the guidelines in paragraph 103 to determine the recommended runway length 153 for the first primary runway. For additional primary runways, apply Table 1-1. 154

105. Crosswind Runways.

It is not always possible to achieve the design objective to orient primary runways to provide the 95 percent crosswind component coverage recommended in AC 150/5300-13, Airport Design. In cases where this cannot be done, we recommend a crosswind runway. Even when the 95 percent crosswind coverage standard is achieved for the design airplane or airplane family, certain airplanes with lower crosswind capabilities may not be able to use the primary runway under all

conditions. For airplanes with lesser crosswind capabilities, you may build a crosswind runway. For federally funded projects, the criterion for regular use applies to the design airplane needing the crosswind runway (see paragraph 102.h). Follow the guidelines found in Table 1-2 to determine the recommended runway length for a crosswind runway.

Table 1-1. Runway Length for Additional Primary Runways

Runway Service Type, User	Runway Length for Additional Primary Runways	
Capacity Justification, Noise Mitigation	100% of the primary runway	
Separating Airplane Classes – Smaller, slower vs. larger, faster airplanes	Recommended runway length for the less demanding design airplane or airplane family	

Table 1-2. Runway Length for Crosswind Runway

Runway Service	Runway Length for Crosswind Runways
Scheduled ¹ Such as Commercial Service Airports	100% of the primary runway length when built for the same individual design airplane or airplane family that uses the primary runway
Non-Scheduled ² Such as General Aviation Airports	100% of the recommended runway length determined for the lower crosswind capable airplanes using the primary runway

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- 1. Transport service operated over routes pursuant to published flight schedules that are openly advertised with dates or times (or both) or otherwise made readily available to the general public or pursuant to mail contracts with the U.S. Postal Service (Bureau of Transportation Statistics, Department of Transportation (DOT)).
- **2.** Revenue flights, such as charter flights that are not operated in regular scheduled service, and all non-revenue flights incident to such flights (Bureau of Transportation Statistics, DOT). For Federally funded projects, see paragraph 102.h.

106. Minimum Runway Lengths.

- The need to conduct operations on the runway during periods of Instrument Meteorological
- 177 Conditions (IMC) may require a minimum runway length of more than calculated by airplane
- performance. The need for this capability is highest among airplanes used for business, air taxi,
- and cargo purposes. See AC 150/5300-13 regarding minimum runway lengths for various
- instrument operations.

107. Runway Length Based on Declared Distances Concept.

- Do not apply the declared distances concept to overcome safety deficiencies for new runways or
- runway extensions. See AC 150/5300-13 for information related to declared distances.

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Chapter 2. Runway Lengths for Small Propeller-Driven Airplanes

201. Design Guidelines.

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The design procedure for small propeller-driven airplanes requires the following information: the

- design airplane(s) to be accommodated, V_{REF} or approach speed, number of passenger seats,
- airport elevation above mean sea level, and the mean daily maximum temperature of the hottest
- month at the airport. Apply the guidance from paragraph 203, 204, or 205, as appropriate, to
- obtain the recommended runway length. For this airplane category, no further adjustment to the
- length obtained from Figure 2-1 or Figure 2-2 is necessary.

202. Design Approach.

For purposes of design, we group small propeller-driven airplanes according to approach speed.

We further divide the highest approach speed group into those airplanes having fewer than 10

passenger seats and those having 10 or more passenger seats. See Table 2-1. When designing a

runway for airplanes having fewer than 10 passenger seats, you may choose to accommodate 95

percent of the fleet or 100 percent of the fleet, as explained in paragraph 205. For these

airplanes, Figure 2-1 and Figure 2-2 show only a single curve for each combination of airport

200 elevation and temperature that takes into account the most demanding operations. You can

determine the recommended runway length from airplane flight manuals for the airplanes to be

accommodated by the airport in lieu of the runway length curves in <u>Figure 2-1</u> and <u>Figure 2-2</u>.

203 This design procedure may be desirable when considering some operational requirements.

Table 2-1. Families of Small Propeller-Driven Airplanes for Runway Length Recommendations

Airplane Maximum Certifica	Location of Design Guidelines	
Approach Speeds less than	Paragraph <u>203</u>	
Approach Speeds of at lea	Paragraph <u>204</u>	
Approach Speeds of 50	With Fewer than 10 Passengers	Paragraph <u>205</u> Figure 2-1
knots or more	With 10 or more Passengers	Paragraph <u>205</u> Figure 2-2

203. Small Propeller-Driven Airplanes with Approach Speeds of Less Than 30 Knots.

We consider propeller-driven airplanes with approach speeds of less than 30 knots to be short takeoff and landing or ultralight airplanes. Their recommended runway length is 300 feet (92 meters) at mean sea level. Increase the length of runways located above mean sea level at the rate of 0.03 x the airport elevation above mean sea level.

204. Small Propeller-Driven Airplanes with Approach Speeds of 30 Knots or More but

- 212 Less Than 50 Knots.
- The recommended runway length is 800 feet (244 meters) at mean sea level. Increase the length
- of runways above mean sea level at the rate of 0.08 x the airport elevation above mean sea level.
- 215 205. Small Propeller-Driven Airplanes with Approach Speeds of 50 Knots or More.
- 216 <u>Figure 2-1</u> and <u>Figure 2-2</u> provide the recommended runway lengths based on the seating
- capacity and the mean daily maximum temperature of the hottest month of the year at the airport.
- The fleet we used in the development of the figures consisted of small propeller-driven airplanes
- certificated in the United States. Figure 2-1 provides curves for two design conditions for small
- propeller-driven airplanes with fewer than 10 passenger seats 95 and 100 percent of the fleet.
- The differences between the two percentage categories are based on the airport's location and the
- amount of existing or planned aviation activities. The selection of percentage of fleet is a
- planning decision and beyond the scope of this AC. Figure 2-2 provides curves for small
- propeller-driven airplanes with 10 or more passenger seats. For airports above 3,000 feet (900 m)
- MSL, use the 100 percent of fleet chart of Figure 2-1 instead of Figure 2-2. Both figures provide
- examples that start with the horizontal temperature axis, then proceed vertically to the applicable
- 227 airport elevation curve, followed by proceeding horizontally to the vertical axis to read the
- recommended runway length.

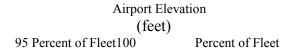
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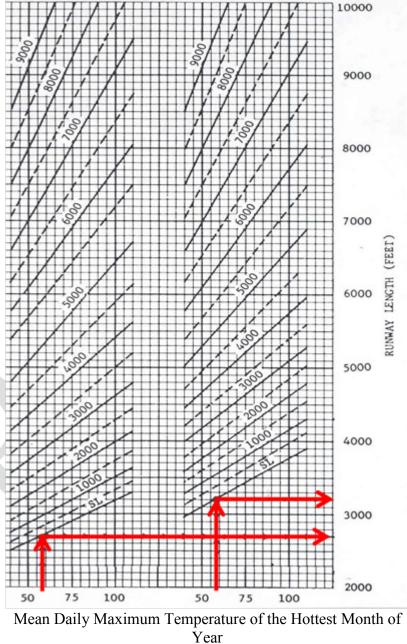
206. Development of the Runway Length Curves.

- 230 Title 14 Code of Federal Regulations Part 23, Airworthiness Standards: Normal, Utility, and
- 231 Acrobatic Category Airplanes, prescribes airworthiness standards for the issuance of small
- 232 airplane type certificates. Individual airplane flight manuals contain the performance information
- for each airplane (for example, as defined in Section 23.51, Takeoff; Section 23.75, Landing; and
- Section 2.1587, Performance Information). The flight manuals provide this information to assist
- 235 the airplane operator in determining the runway length necessary to operate safely. We
- selectively grouped performance information from those manuals to develop the runway length
- curves in Figure 2-1 and Figure 2-2. Figure 2-1 is based on required takeoff and landing
- distances. Figure 2-2 also includes accelerate-stop distances required for operations conducted
- under 14 CFR Part 135, Operating Requirements: Commuter and On Demand Operations and
- 240 Rules Governing Persons on Board such Aircraft. We used the following conditions in
- 241 developing the curves:
- Zero headwind component.
- Maximum certificated takeoff and landing weights.
- Optimum flap setting for the shortest runway length.
- Variable airport elevation and temperature.
- Other factors, such as relative humidity and runway elevation range, also have a variable effect
- on runway length but are not accounted for in certification. However, we accounted for these
- other factors in the runway length curves by increasing the takeoff or landing distance

(whichever was longer) of the group's most demanding airplane by 10 percent for the various combinations of airport elevation and temperature in <u>Figure 2-1</u> and <u>Figure 2-2</u>. These curves are based on the best information available at the time, but may not be accurate for all airplanes at all temperatures and elevations. If the fleet mix to operate at the airport is known, consult the manufacturers' literature to determine actual runway length requirements.







(Degrees F)

Figure 2-1. Determination of Runway Length for Small Propeller-Driven Airplanes with Fewer than 10 Passenger Seats

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Example:

Level

solid lines.

Temperature (mean day max hot

Note: Dashed lines shown in the table are mid values of adjacent

Recommended Runway Length:

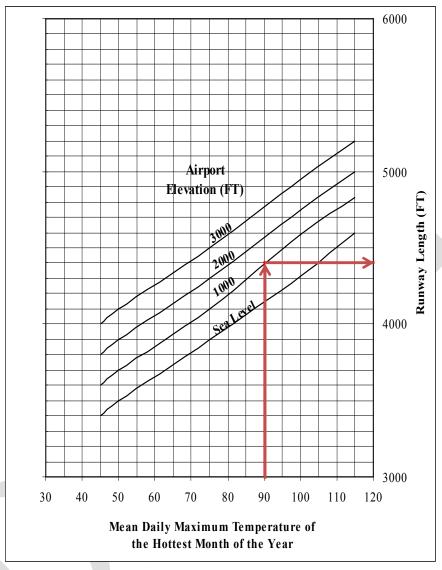
For $95\% = 2{,}700$ feet (823 m)

For 100% = 3,200 feet (975 m)

Airport Elevation: Mean Sea

month): 59°F (15°C)

Runway Length Curves



(Degrees F)

Figure 2-2. Determination of Runway Length for Small Propeller-Driven Airplanes Having
10 or More Passenger Seats
(Excludes Pilot and Co-pilot)

Example: Temperature (mean day max hot month) 90°F (32°C)
Airport Elevation (MSL) 1,000 ft. (328 m)
Recommended Runway Length 4,400 ft. (1,341 m)

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Note: For airport elevations above 3,000 feet (915 m), use the 100 percent of fleet grouping in <u>Figure 2-1</u>.

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Chapter 3. Runway Lengths for Large Airplanes and Light Jets

301. Design Airplane(s).

- The recommended runway length obtained for this category of airplanes is based on using the
- performance charts published by airplane manufacturers (APMs) for individual airplanes. While
- 269 airlines do interchange airplane models, performance characteristics of airplanes with similar
- seating capacity vary too widely to allow runway lengths to be designed based on similarities
- between airplane models. It is wise to consult with airlines regarding possible airplane
- 272 substitutions.

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302. General Design Procedure.

- The recommended runway length for large airplanes and light jets is a function of the design airplanes' performance.
 - **a.** Take-off Weights.
 - (1) Long-haul routes. Use the maximum certificated takeoff weight.
 - (2) Short-haul routes. The length of haul will determine the operating takeoff weight for the design airplane(s). For federally funded projects, take into account the length of haul that is flown by airplanes on a regular use basis. Determine whether to use MTOW by considering the payload break point shown in Figure 3-1 in conjunction with the payload-range charts provided by APMs. Figure 3-1 illustrates a generic payload-range chart with range and payload axes, the payload break point, and the boundary parameters. For length of haul ranges that equal or exceed the payload break point, set the operating takeoff weight to the MTOW. For all the other cases, set the design operating takeoff weight to the actual operating takeoff weight. AC 120-27, Aircraft Weight and Balance Control, provides average weight values for passengers and baggage for payload calculations for short-haul routes.
 - (3) Weight adjustments. In some cases, a lower weight than indicated by (1) and (2) above must be used, based on a tire speed limit. This limit will usually be built into APM charts. The takeoff weight may also be decreased to the climb limited takeoff weight or the obstacle clearance takeoff weight.
 - (a) Climb limited takeoff weight. The operating takeoff weight may be limited by the ability of the airplane to climb at a certain rate. However, designing based on the lower takeoff weight corresponding to a high temperature will result in a shorter runway than necessary for higher weights on cooler days. Use the STD for such situations.
 - **(b)** Obstacle clearance takeoff weight. Information necessary for runway length design based on obstacle clearance is not provided in APMs. If there are obstacles beyond the departure end of the runway that may affect the operating takeoff weight, consult with airplane operators.
 - **b.** Landing Weight. Use the maximum certificated landing weight.

- c. Flap Setting. Use flap settings that result in the shortest necessary runway lengths.
- 302 **d.** Necessary information includes the airport elevation, the mean daily maximum temperature of the hottest month at the airport, dry or wet runway conditions, and the runway elevation range. The runway elevation range may not be known until a preliminary runway length is determined, so the design procedure may take several iterations.
- e. Apply the procedures in this chapter to each APM to obtain separate takeoff and landing runway length recommendations.
- 308 **f.** Apply any takeoff and landing length adjustments, if necessary, to the resulting lengths.

303. Airport Planning Manual (APM).

- Each airplane manufacturer's APM provides performance information on takeoff and landing
- runway length requirements for different airplane operating weights, airport elevations, flap
- settings, engine types, and other parameters. Airplane manufacturers do not present the data in a
- standard format. However, there is sufficient consistency in the presentation of the information
- 315 to determine the recommended runway length as described in paragraphs 306, 307, and 308.
- 316 Airport Planning Manuals (APMs) provide basic runway length requirements. Aircraft operators
- may justify additional runway length.

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318 304. United States Federal Aviation Regulations (FAR) and European Joint Aviation

- Regulations (JAR) or Certification Specifications (CS).
- a. Certification specifications have replaced the European JARs that were previously issued by the Joint Aviation Authorities of Europe. Today the European Aviation Safety Agency (EASA) issues all CS.
- b. Some APM charts provide curves for both FAR and JAR (or CS) regulations. For air carriers under the authority of the United States, use the curves labeled "FAR." For foreign air carriers who receive approval from their respective foreign authorities, such as EASA, use the curves authorized by the foreign authority, i.e., curves labeled "JAR," "CS", or "FAR."
- 327 305. Airplane Manufacturer Websites.
- 328 Appendix 1 provides the website addresses of the various airplane manufacturers to assist in
- obtaining APMs or for further consultation.
- 330 306. Recommended Landing Lengths.
- For the airplane model with the corresponding engine type (if provided):
- a. Locate the landing chart with the highest landing flap setting.
- b. Enter the horizontal weight axis with the operating landing weight equal to the maximum certificated landing weight.

c. Proceed vertically to the airport elevation curve, sometimes labeled "pressure altitude." Interpolation between curves is allowed. Some charts show both the "dry runway" and "wet runway" curves. Use the "wet runway" curve only for turbojet-powered airplanes. See paragraph 306.e below for turbo-jet powered airplanes when the chart only provides "dry runway" curves.

- **d.** Proceed horizontally from the wet runway curve to the length axis to read the landing runway length.
- e. Address wet, slippery runway surface conditions only for landing operations and only for turbojet-powered airplanes. Many airplane manufacturers' APMs for turbojet-powered airplanes provide both dry runway and wet runway landing curves. If an APM provides only the dry runway condition, then increase the obtained dry runway length by 15%.
 - **f.** It is not necessary to adjust the landing length for a non-zero runway elevation range.

307. Recommended Takeoff Lengths.

For the airplane model with the corresponding engine type (if provided):

a. Determine the design temperature, using an airport temperature of the mean daily maximum temperature of the hottest month at the airport. APMs provide takeoff runway lengths as a function of airport elevation and standard day temperatures (SDT). Table 3-1 shows how APMs correlate SDTs with airport elevations. Many airplane manufacturers provide at least two takeoff runway length requirement charts, one at SDT and one at SDT plus some additional temperature, for example, SDT + 27°F (SDT + 15°C). Use the chart based on SDT when the mean daily maximum temperature of the hottest month at the airport is equal to, or no more than $3^{\circ}F$ (1.7°C) higher than, the temperature used in the chart. For example, a SDT+ $27^{\circ}F$ (SDT + $15^{\circ}C$) chart could be used when airport temperatures are equal to or less than $59^{\circ}F + 27^{\circ}F + 3^{\circ}F = 89^{\circ}F$ ($15^{\circ}C + 15^{\circ}C + 1.7^{\circ}C = 32^{\circ}C$) at an airport at sea level. If no SDT chart is available for the recorded airport temperature, consult the airplane manufacturer directly to obtain the takeoff length requirement under the same conditions outlined in this paragraph.

Table 3-1. Relationship between Airport Elevation and Standard Day Temperature

Airport Elevation 1	Standard Day Temperature 1 (SDT)
Feet	° F
0	59
2,000	52
4,000	45
6,000	38
8,000	31

Note:

1. Linear interpolations between airport elevations and between SDT values are permissible.

b. Locate the takeoff chart with dry runway conditions for the appropriate temperature. "Zero wind" is used, as it is the wind condition requiring the longest runway length. If the chart does not indicate the "zero wind" or "zero effective runway gradient" conditions, assume they are equal to zero.

c. Enter the horizontal weight axis with the operating takeoff weight.

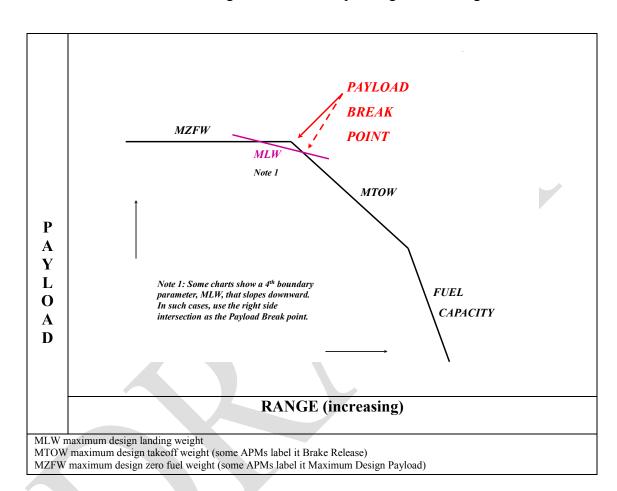


Figure 3-1. Generic Payload/Range Chart

- **d.** Proceed vertically to the airport elevation curve without exceeding any indicated limitations, such as maximum brake energy limit, tire speed limit, etc. Interpolate between curves, if necessary. A takeoff chart may contain under the "Notes" section the condition that linear interpolation between elevations is invalid. Because the application of the takeoff chart is for airport design and not for flight operations, interpolation is allowed. Some airport elevations curves show various flap settings along the curve. In such cases, continue to use the same airport elevation curve.
- **e.** Proceed horizontally from the airport elevation curve to the runway length axis to read the takeoff runway length.
- **f.** Adjust the obtained takeoff runway length for runway elevation range by increasing the length by 10 feet (3 m) per foot (0.3m) of runway elevation range.

308. Final Recommended Runway Length.

The final recommended runway length is the longest resulting length after all adjustments for all design airplanes.

309. Example 1.

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a. General.

Use published information in the airplane manufacturer's Airport Planning Manual (APM). The airport designer will determine the separate length requirements for takeoff and landing, make necessary adjustments to those lengths, and then select the longest length as the recommended runway length. This example also assumes that the length of haul is of sufficient range so that the takeoff operating weight is set equal to the MTOW.

b. Design Conditions.

The calculations will use the following design conditions (see also <u>Table 3-3</u>).

Table 3-2. Design Conditions

Airplane	Boeing 737-900 (CFM56-7B27 Engines)	
Mean daily maximum temperature of hottest month at the airport	84° Fahrenheit (28.9°C)	
Airport elevation	1,000 feet	
Maximum design landing weight	146,300 pounds	
Maximum design takeoff weight (long haul)	164,000 pounds	
Runway Elevation Range	20 feet	

Table 3-3. Boeing 737-900 General Airplane Characteristics *

Characteristics	Units	Model 737-900, -900 with winglets		
Max design	Pounds	164,500	174,700	
Taxi weight	Kilograms	74,616	79,243	
Max design	Pounds	164,000 ²	174,200	
Takeoff weight	Kilograms	74,389	79,016	
Max design	Pounds	146,300 ³	147,300	
Landing weight	Kilograms	66,361	66,814	
Max design	Pounds	138,300	140,300	
Zero fuel weight	Kilograms	62,732	63,639	
Operating	Pounds	94,580	94,580	
Empty weight ¹	Kilograms	42,901	42,901	
Max structural	Pounds	43,720	45,720	
Payload	Kilograms	19,831	20,738	
Seating capacity ¹	Two-class	177	177	
	All-economy	189	189	
Max cargo	Cubic feet	1,835	1,835	
- Lower deck	Cubic meters	52.0	52.0	
Usable fuel	Us gallons	6875	6875	
	Liters	26,022	26,022	
	Pounds	46,063	46,063	
	Kilograms	20,894	20,894	

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Notes: 1. Operating empty weight for baseline mixed class configuration. Consult with airline for specific weights and configurations.

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2. Maximum takeoff weight (used in example).

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3. Maximum landing weight (used in example).

^{*} Embraer granted permission for use of this chart.

401 Calculations. c. The steps used in the calculations are those provided in paragraphs 306, 307, and 308, noting 402 applicable conditions. Figure 3-2 and Figure 3-3 are used for the calculations. 403 (1) Recommended Landing Lengths. 404 (a) Locate the landing chart with the highest landing flap setting. The 405 Boeing 737-900 APM provides only one landing chart: for a flap setting of 30-degrees. This 406 chart is reproduced as Figure 3-2. 407 408 **(b)** Enter the horizontal weight axis with the operating landing weight equal to the maximum certificated landing weight (MLW). The MLW = 146,300 pounds. Note 409 that this APM does not provide landing length curves for the MLW of an airplane with winglets. 410 It is not acceptable to use the lower MLW shown in the chart for an airplane with winglets, as 411 this would result in a shorter runway than necessary. In such a case, it is necessary to contact the 412 413 airplane manufacturer. (c) Proceed vertically and interpolate between the airport elevation's 414 "wet" curves of sea level and 2,000 feet for the 1,000-foot wet value. Wet curves are selected 415 because the airplane is a turbo-jet powered airplane. 416 (d) Proceed horizontally to the length axis to read the landing runway 417 length of just under 7,000 feet. 418 (e) Do not adjust the obtained length since the "wet runway" curve was 419 used. See paragraph 306.e if only "dry" curves are provided. 420 421 (f) The length recommendation is 7000 feet. Lengths of 30 feet and over are rounded to the next 100-foot interval. 422

DO NOT USE FOR DISPATCH

- STANDARD DAY, ZERO WIND

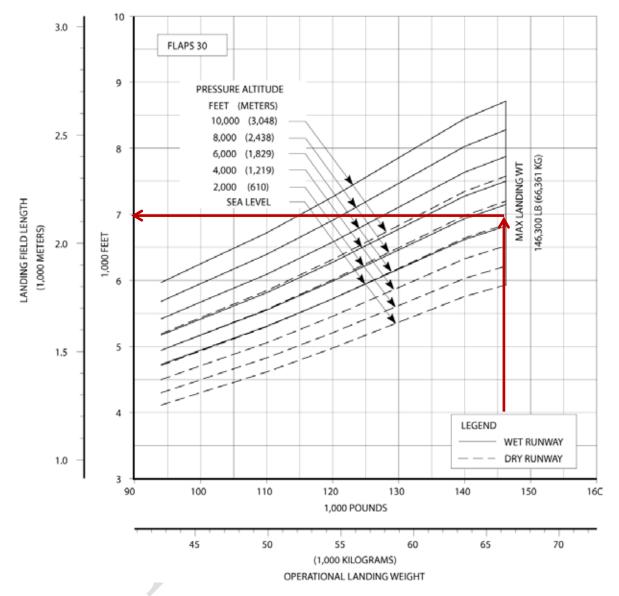
- AUTO SPOILERS OPERATIVE

- ANTI-SKID OPERATIVE

- ZERO RUNWAY GRADIENT

Landing Field Length 737-900/-900W (CFM56-7B Series)

- CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE PRIOR TO FACILITY DESIGN



F.A.R. LANDING RUNWAY LENGTH REQUIREMENTS - FLAPS 30 MODEL 737-900

Figure 3-2. Landing Runway Length for Boeing 737-900 (CFM56-7B Engines)*

* Boeing granted permission for use of this charts.

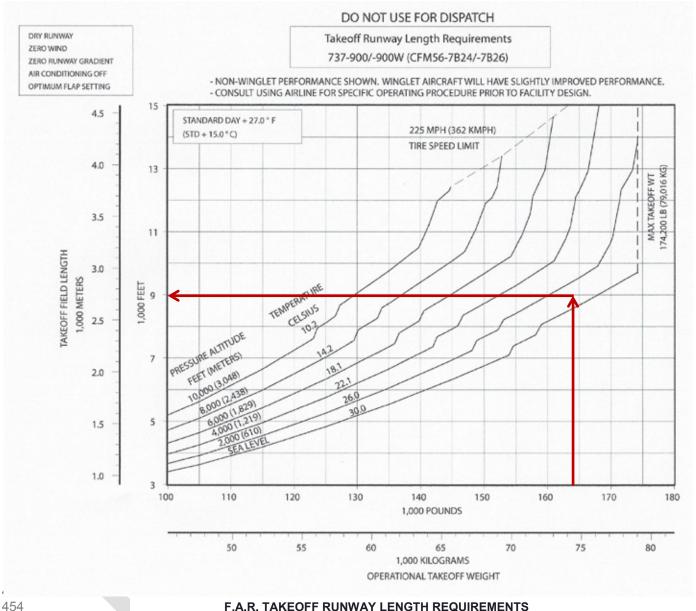
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(2) Recommended Takeoff Lengths. 428 (a) Determine the design temperature, using the mean daily maximum 429 temperature of the hottest month at the airport. 430 **(b)** Locate the takeoff chart with dry runway conditions for the appropriate 431 432 temperature, using zero wind (Figure 3-3). The Boeing 737-900 APM provides a takeoff chart at SDT + 27°F (SDT + 15°C) applicable to the various flap settings. This chart is reproduced 433 as Figure 3-3. Referring to Table 3-1 and interpolating between elevations of sea level and 2000 434 ft., the SDT is 55°F. So this chart can be used for an airport at 1000 ft. MSL where the mean 435 daily maximum temperature of the hottest month is equal to or less than 85.5°F (29.7°C). Since 436 the given temperature for this example of 84°F (28.9°C) falls within this range, select this chart. 437 (c) Enter the horizontal weight axis with the maximum takeoff weight of 438 164,000 pounds. 439 (d) Proceed vertically and interpolate between the airport elevation curves 440 of sea level and 2.000 feet for the 1.000-foot value. 441 (e) Proceed horizontally from the airport elevation curve to the runway 442 length axis to read the takeoff runway length of 9,000 feet. 443 (f) Adjust the takeoff runway length for runway elevation range by 444 increasing the length by 10 feet (3 m) per foot (0.3m) of difference between the high and low 445 points of the runway centerline. 446 $9,000 + (20 \times 10) = 9,000 + 200 = 9,200$ feet 447 (g) The takeoff length recommendation is 9,200 feet. 448 Landing Length: 7,000 Feet 449 Takeoff Length: 9,200 Feet 450 Select the longest length for airport design. In this case, the takeoff length of 9,200 feet is the 451 recommended runway length. 452



F.A.R. TAKEOFF RUNWAY LENGTH REQUIREMENTS

STANDARD DAY +27°F (SDT + 15°C), DRY RUNWAY

MODEL 737-9001-900W (CFM56-7B24/-7B26 ENGINES AT 24,000 LB SLST)

JULY 2010

Figure 3-3. Takeoff Runway Length for Boeing 737-900 (CFM56-7B Engines)*

* Boeing granted permission for use of this chart.

310. Example 2.

Use published information in the airplane manufacturer's airport planning manual (APM). The airport designer will determine the separate length requirements for takeoff and landing, make necessary adjustments to those lengths, and then select the longest length as the recommended runway length. This example involves a short haul and an airport at 4000 ft. MSL.

Design Conditions. a.

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The calculations will use the following design conditions (see also Table 3-3).

Table 3-4. Design Conditions

Airplane	Boeing 737-900 with winglets (CFM56-7B27 Engines)
Mean daily maximum temperature of hottest month at the airport	74° Fahrenheit (23.3°C)
Airport elevation	4,000 feet
Maximum design landing weight	146,000 pounds
Length of haul	1000 NM
Runway Elevation Range	30 feet

b. Calculations.

The steps used in the calculations are those provided in paragraphs 306, 307, and 308, noting applicable conditions. Figure 3-4, Figure 3-5, and Figure 3-6 are used for the calculations.

- Recommended Landing Lengths. **(1)**
- (a) Locate the landing chart with the highest landing flap setting: The Boeing 737-900 APM provides only one landing chart: for a flap setting of 30-degrees. This chart is reproduced as Figure 3-4.
- **(b)** Enter the horizontal weight axis with the operating landing weight equal to the maximum certificated landing weight (MLW). The MLW = 146,000 pounds. Note that this APM does not provide landing length curves for the MLW of an airplane with winglets. It is not acceptable to use the lower MLW shown in the chart for an airplane with winglets, as this would result in a shorter runway than necessary. In such a case, it is necessary to contact the airplane manufacturer.
- (c) Proceed vertically to the airport elevation's "wet" curve for 4,000-feet. The wet curve is selected because the airplane is a turbo-jet powered airplane. 482
- (d) Proceed horizontally to the length axis to read the landing runway 483 length of 7,500 feet. 484

(e) Do not adjust the obtained length since the "wet runway" curve was used. See paragraph 306.e if only "dry" curves are provided.

(f) The length recommendation is 7500 feet.

DO NOT USE FOR DISPATCH

Landing Field Length

737-900/-900W (CFM56-7B Series)

- STANDARD DAY, ZERO WIND
- AUTO SPOILERS OPERATIVE
- ANTI-SKID OPERATIVE

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- ZERO RUNWAY GRADIENT
- CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE PRIOR TO FACILITY DESIGN

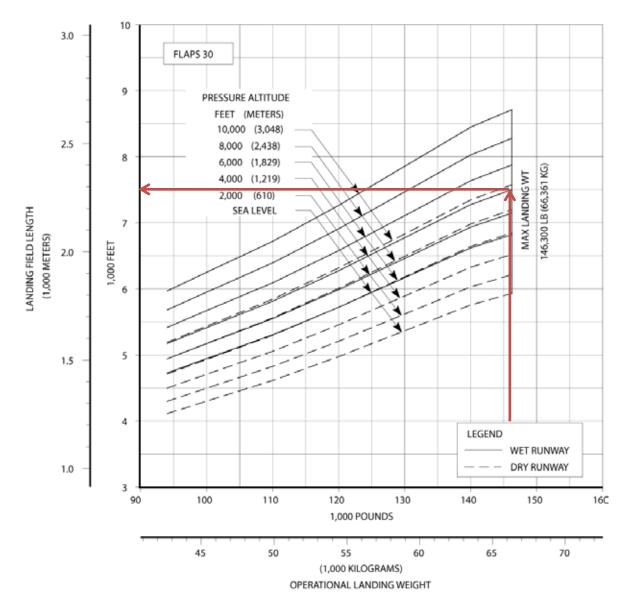


Figure 3-4. Landing Runway Length for Boeing 737-900 (CFM56-7B Engines)*

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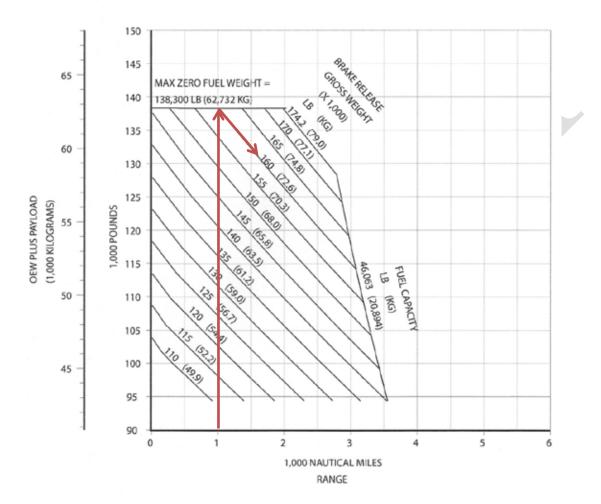
^{*} Boeing granted permission for use of this chart.

491 **(2)** Recommended Takeoff Lengths. (a) Determine the design temperature, using an airport temperature of the 492 mean daily maximum temperature of the hottest month at the airport. The Boeing 737-900 APM 493 provides a takeoff chart at the standard day + 27°F (SDT + 15°) temperature applicable to the 494 various flap settings. This chart is reproduced as Figure 3-6. Referring to Table 3-1, the SDT at 495 4000 ft. MSL is 45°F. So this chart can be used for an airport at 4000 ft. MSL where the mean 496 daily maximum temperature of the hottest month is equal to or less than $45^{\circ}F + 27^{\circ}F + 3^{\circ}F =$ 497 75° F (7.2° C + 15° C + 1.7° C = 23.9° C). Since the given temperature for this example of 74° F 498 (23.3°C) falls within this range, select this chart. 499 500 (b) Locate the takeoff chart with dry runway conditions for the appropriate temperature, using zero wind (Figure 3-6). 501 502 (c) Determine the operating takeoff weight based on a haul length of 1000 NM. Enter the horizontal haul length axis of the payload/range chart (Figure 3-5) at 1000 NM 503 and proceed vertically to the MZFW limit of 138, 300 lbs., intersecting the diagonal line 504 505 representing an operating takeoff weight of 160,000 lbs. (d) Enter the horizontal weight axis of the takeoff length chart (Figure 506 507 3-6) with the operating takeoff weight of 160,000 pounds. (e) Proceed vertically to the airport elevation curve for 4,000 feet MSL. 508 **(f)** Proceed horizontally from the airport elevation curve to the runway 509 length axis to read the takeoff runway length of 10,000 feet. 510 (g) Adjust the takeoff runway length for runway elevation range by 511 increasing the length by 10 feet (3 m) per foot (0.3m) of difference between the high and low 512 points of the runway centerline. 513 $10.000 + (30 \times 10) = 10.000 + 300 = 10.300$ feet 514 The takeoff length recommendation is 10,300 feet. 515

DO NOT USE FOR DISPATCH

Payload/Range 737-900/-900W (CFM56-7B Series)

- STANDARD DAY, ZERO WIND
- CRUISE MACH = LRC
- NORMAL POWER EXTRACTION AND AIR CONDITIONING BLEEDS
- TYPICAL MISSION RULES
- NON-WINGLET PERFORMANCE SHOWN. WINGLET AIRCRAFT WILL HAVE SLIGHTLY GREATER RANGE.
- CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE AND OEW PRIOR TO FACILITY DESIGN.



PAYLOAD/RANGE FOR LONG-RANGE CRUISE

MODEL 737-900

Figure 3-5. Payload/Range for Boeing 737-900 (CFM56-7B Engines)*

* Boeing granted permission for use of this chart.

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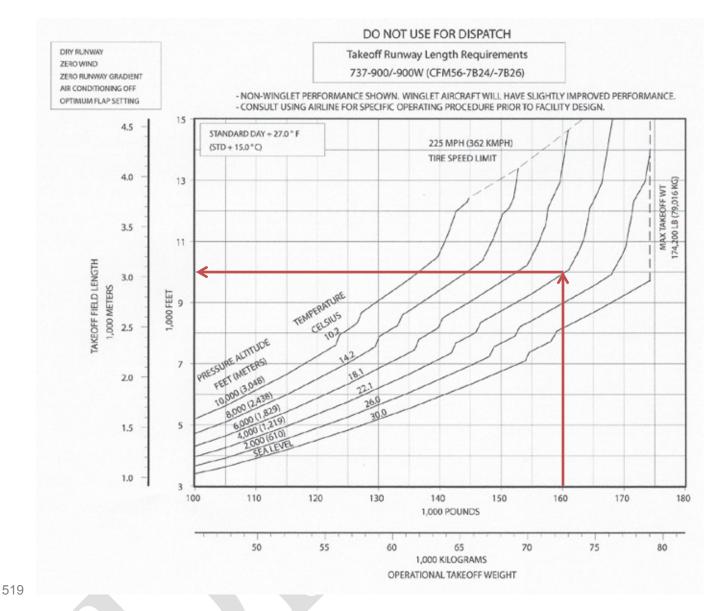


Figure 3-6. Takeoff Runway Length for Boeing 737-900 (CFM56-7B Engines)*

* Boeing granted permission for use of this chart.

Landing Length: 7,500 Feet

Takeoff Length: 10,300 Feet

Select the longest length for airport design. In this case, the takeoff length of 10,300 feet is the recommended runway length.

311. Example **3**.

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Use published information in the airplane manufacturer's airport planning manual (APM). The airport designer will determine the separate length requirements for takeoff and landing, make

necessary adjustments to those lengths, and then select the longest length as the recommended runway length. This example also assumes that the length of haul is of sufficient range so that the takeoff operating weight is set equal to the MTOW. However, the example also involves a high airport elevation, requiring a check of climb limited takeoff weight.

a. Design Conditions.

The calculations will use the following design conditions (see also).

Table 3-5. Design Conditions

Airplane	Embraer 120 Brasilia RT	
Mean daily maximum temperature of hottest month at the airport	64° Fahrenheit (17.8°C)	
Airport elevation	6,000 feet	
Maximum design landing weight	24802 pounds	
Maximum takeoff weight	25353 pounds	
Runway Elevation Range	30 feet	

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Table 3-6. Embraer 120 General Airplane Characteristics*



€ EMBRAEREMBÍ2O **Brasilia**AIRPORT PLANNING

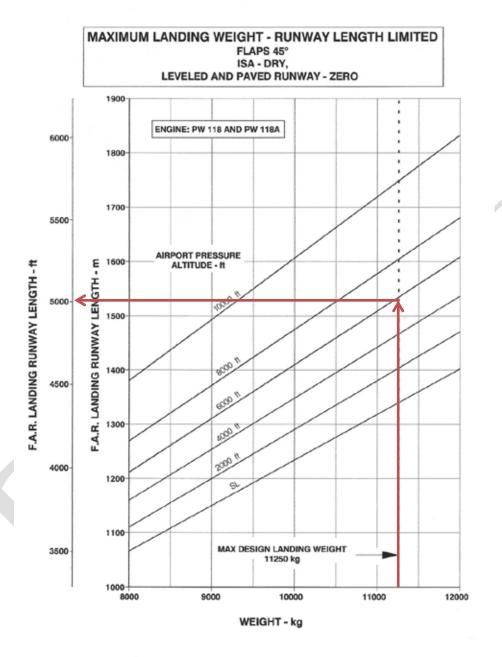
	MODEL			
DESIGN WEIGHT	RT		ER	
	kg	lb	kg	lb
Maximum Taxi Weight	11580	25529	12070	26610
Maximum Landing Weight	11250	24802	11700	25794
Maximum Takeoff Weight	11500	25353	11990	26433
Maximum Zero Fuel Weight	10500	23148	10900	24030
Equipped Empty Weight (PAX) (Average Weight)	7072	15591	7177	15824
Operating Weight (PAX) (Average Weight)	7230	15939	7628	16817
Operating Weight (Quick-change - PAX)	-	-	7680	16931
Operating Weight (Quick-change - Cargo)	-	-	7400	16931
Operating Weight (Combi)	-	-	7700	16975
Operating Weight (Full Cargo)	-	-	7160	15785
Maximum Payload (PAX) (Average)	3270	7209	3272	7213
Maximum Payload (Quick-change - PAX)	-	-	3220	7099
Maximum Payload (Quick-change - Cargo)	-	-	3500	7716
Maximum Payload (Combi)	-	-	3200	7054
Maximum Payload (Full Cargo)			3740	8245

Design Weights for Standard Configuration

^{*} Embraer granted permission for use of this chart.

539	b. Calculations.
540 541	The steps used in the calculations are those provided in paragraphs <u>306</u> , <u>307</u> , and <u>308</u> , noting applicable conditions. <u>Figure 3-7</u> , <u>Figure 3-8</u> , and <u>Figure 3-9</u> are used for the calculations.
542	(1) Recommended Landing Lengths.
543 544 545	(a) Locate the landing chart with the highest landing flap setting: The Embraer Brasilia APM provides only one landing chart: for a flap setting of 45 degrees. This chart is reproduced as <u>Figure 3-7</u> .
546 547	(b) Enter the horizontal weight axis with the operating landing weight equal to the maximum certificated landing weight (MLW). The MLW = $24,802$ pounds.
548 549	(c) Proceed vertically to the airport elevation's "dry" curve for 6,000-feet. The dry curve is selected because the airplane is not a turbo-jet powered airplane.
550 551	(d) Proceed horizontally to the length axis to read the landing runway length of 5,000 feet.





FAR Landing Runway Length Requirements - Flaps 45°

Figure 3-7. Landing Runway Length for Embraer 120 Brasilia RT*

* Embraer granted permission for use of this chart.

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(2) Recommended Takeoff Lengths.

(a) Determine the design temperature, using an airport temperature of the mean daily maximum temperature of the hottest month at the airport. The Embraer Brasilia APM provides a takeoff chart at the standard day $+ 27^{\circ}F$ (SDT $+ 15^{\circ}$) temperature applicable to the various flap settings. This chart is reproduced as <u>Figure 3-9</u>. Referring to <u>Table 3-1</u>, the SDT at 6000 ft. MSL is 38°F. So this chart can be used for an airport at 6000 ft. MSL where the mean daily maximum temperature of the hottest month is equal to or less than $38^{\circ}F + 27^{\circ}F + 3^{\circ}F = 68^{\circ}F$ (3.3°C + 15°C + 1.7°C = 20°C). Since the given temperature for this example of 64°F (17.8°C) falls within this range, select this chart.

- **(b)** Locate the takeoff chart with dry runway conditions for the appropriate temperature, using zero wind (<u>Figure 3-9</u>).
 - (c) Determine the operating takeoff weight based on climb limited performance, using the STD. Enter the horizontal haul length axis of the climb limited takeoff weight chart (<u>Figure 3-8</u>) at the STD of 38°F (3.3°C) and proceed vertically to the diagonal line representing an airport elevation of 6000 ft. MSL.
 - (d) Proceed horizontally to the weight axis to read the operating takeoff weight of 26,500 pounds (12,000 kg). This is above the MTOW, so no adjustment based on climb performance is required. Use the MTOW.
- (e) Enter the horizontal weight axis of the takeoff length chart (Figure 3-9) with the MOTW of 25,353 pounds (11,500 kg).
 - (f) Proceed vertically to the airport elevation curve for 6,000 feet MSL.
- (g) Proceed horizontally from the airport elevation curve to the runway length axis to read the takeoff runway length of 7,100 feet.
- (h) Adjust the takeoff runway length for runway elevation range by increasing the length by 10 feet (3 m) per foot (0.3m) of difference between the high and low points of the runway centerline.

$$7,100 + (30 \times 10) = 7,100 + 300 = 7,400$$
 feet

- The takeoff length recommendation is 7,400 feet.
- Landing Length: 5,000 Feet
- Takeoff Length: 7,400 Feet
- Select the longest length for airport design. In this case, the takeoff length of 7,400 feet is the recommended runway length.

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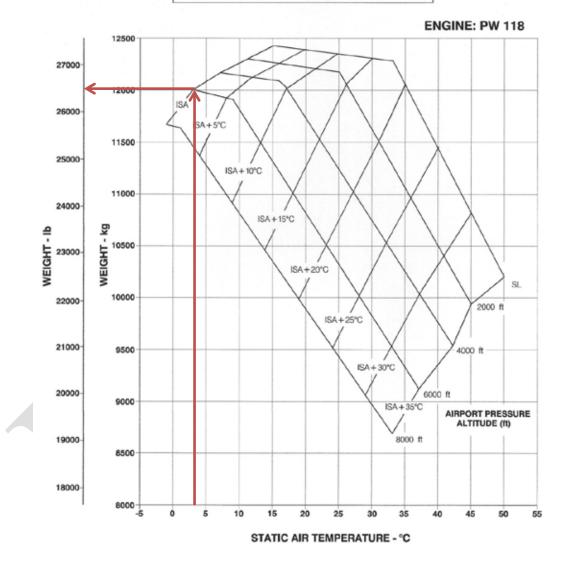
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FAR Takeoff Weight Requirements - (PW 118 Engines)

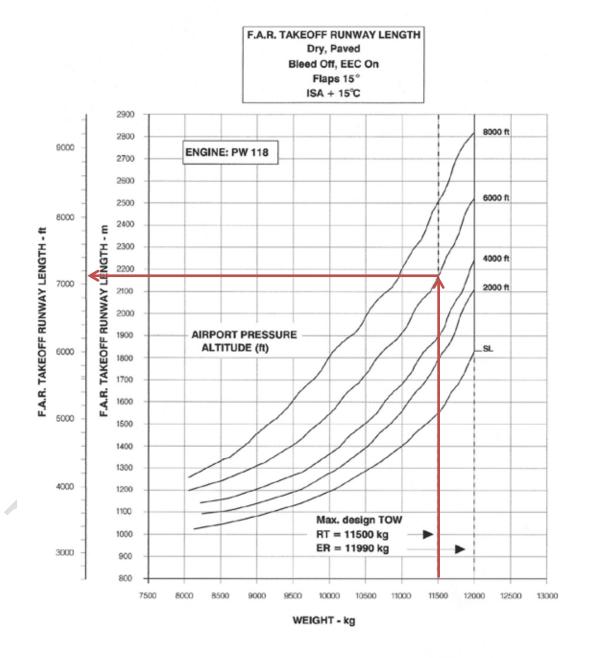
Figure 3-8. Climb Limited Takeoff Weight – Embraer 120 Brasilia RT*

* Embraer granted permission for use of this chart.

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FAR Takeoff Runway Length Requirements - ISA + 15°C Conditions

Figure 3-9. Takeoff Runway Length for Embraer 120 Brasilia RT*

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^{*} Embraer granted permission for use of this chart.

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Appendix 1. Websites of Airplane Manufacturers

Table 1-1. Websites of Airplane Manufacturers

Manufacturer	Website
Airbus	www.airbus.com
Antonov	www.antonov.com
BAE Systems (military aircraft)	www.baesystems.com
Boeing	www.boeing.com/airports
Bombardier	www.bombardier.com
Bristol (British Aircraft Corporation)	www.baesystems.com
Canadair	www.bombardier.com
Dassault Aviation	www.dassault-aviation.com
de Havilland (Hawker Siddley Group, now British Aerospace)	www.dhsupport.com
Embraer	www.embraer.com
Fokker	www.fokker.com
General Dynamics (Gulfstream Aerospace Corporation)	www.generaldynamics.com
Gulfstream (General Dynamics Corporation)	www.gulfstream.com
Hawker Siddeley Group (British Aerospace Corporation)	www.bombardier.com
Ilyushin	www.ilyushin.org
Kawasaki (military aircraft)	www.khi.co.jp

Manufacturer	Website
Lockheed Martin (military aircraft)	www.lockheedmartin.com
Merlin Aircraft	www.merlinaircraft.com
McDonnell Douglas	www.boeing.com
Northrop Grumman	www.northropgrumman.com
Saab Aircraft	www.saabaircraft.com
Short Brothers (Bombardier)	www.bombardier.com
Tupolev	www.tupolev.ru

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Appendix 2. Selected Advisory Circulars, Orders, and Regulations Concerning Runway Length Requirements

A2-1. Related Advisory Circulars

- AC 150/5060-5, Airport Capacity and Delay
 - AC 150/5300-13, Airport Design
 - AC 120-27, Aircraft Weight and Balance Control

601 A2-2. Related Orders

• Order 5100.38, Airport Improvement Program Handbook

Table A2-1. Selected Regulations Concerning Runway Length Requirements

Part	Section
Part 23: Airworthiness standards: Normal, utility, acrobatic, and commuter category airplanes	Section 45: General
Part 25: Airworthiness standards: Transport category airplanes	Section 105: Takeoff
Part 25: Airworthiness standards: Transport category airplanes	Section 109: Accelerate-stop distance
Part 25: Airworthiness standards: Transport category airplanes	Section 113: Takeoff distance and takeoff run
Part 91: General operating and flight rules	Section 605: Transport category civil airplane weight limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 173: General
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 177: Airplanes: Reciprocating engine-powered: Takeoff limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 189: Airplanes: Turbine engine powered: Takeoff limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 195: Airplanes: Turbine engine powered: Landing limitations: Destination airports

Part	Section
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 197: Airplanes: Turbine engine powered: Landing limitations: Alternate airports
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 199: Non-transport category airplanes: Takeoff limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 203: Non-transport category airplanes: Landing limitations: Destination airport
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 205: Non-transport category airplanes: Landing limitations: Alternate airport
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 367: Large transport category airplanes: Reciprocating engine powered: Takeoff limitations
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 375: Large transport category airplanes: Reciprocating engine powered: Landing limitations: Destination airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 377: Large transport category airplanes: Reciprocating engine powered: Landing limitations: Alternate airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 379: Large transport category airplanes: Turbine engine powered and Takeoff limitations
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 385: Large transport category airplanes: Turbine engine powered: Landing limitations: Destination airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 387: Large transport category airplanes: Turbine engine powered: Landing limitations: Alternate airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 393: Large non-transport category airplanes: Landing limitations: Destination airports

Part	Section
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 395: Large non-transport category airplanes: Landing limitations: Alternate airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 398: Commuter category airplanes performance operating limitations



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